Inoculation of earthworms in cropping systems in Madagascar. Consequences on soil and plant properties

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Introduction

Earthworms are soil engineers whose activities have strong impacts on soil functioning, and the provision of ecosystem goods and services. *Pontoscolexcorethrurus* (Glossoscolecidae),an endogeicgeophagous earthworm species commonly found in tropical agricultural soils, is the dominant species in Malagasy cropping systems. This species has been shown to modify soil structure, to increase the availability to plants of nutrients (nitrogen and phosphorus), to affect the dynamics of organic matter, and to modify microorganism activity and diversity. This species thus represents a great potential to increase plant growth.The objective of this study was to determine the effect of *P. corethrurus*inoculation on plant growth and grain yieldsby enhancing P availability.

Methodologies

Study site

The study was conducted at Lazainain the highlands of Madagascar (18°46’55. 59’’ S, 47°32’46. 3’’E, elevation 1274 m).Climate is tropical altitude with a dry and cold seasonfrom May to September and a wet and hot season from October to April. The mean annualtemperature is 20 °C with an average annual rainfall of 1220 mm.The soil is a Ferralsoldominated by*Aristida* species.

Experiment

We tested the introduction of earthworms under conventional (tilled) and conservation (direct seeding mulch-based systems) systems in a rotation rice//maize+dolichus. Each blockwassubmitted to the eight possible combinations of three factors:(i) the inoculation/absence of earthworms, (ii) conventional /conservation systems and (iii) pure culture of rice/mixed culture of maize and dolichus. As we are in the first year of experiment, the soil management factor (conventional vs. conservation) is not considered in this study. For each treatment, four replicates were implemented.Treatments with earthworms wereisolated

by placing metal sheets down to 30 cm and up to 5 cm around the plots. Consequently, earthworms could not escape.At the beginning of the experiment, an aliquot of soil was sampled forfurther analyses.Earthworms were introduced at high densities (equivalent to 75 ind.m^{-2}) at the beginning of the cropping season. *P. corethrurusspecimens* were sampled near the experimental site and added in plots with earthworms.Plants were grown forfour months.Plant growth was regularly followed. At harvest,thirty-two soil monoliths (40 x 40 x 10 cm) were taken from the rice plots. The soil was gently and manually disaggregatedto checkearthworm presence. Soil properties (N and P contents, bulk density) were analysed.Plant biomass and yield werealso calculated, as well as the concentration of N and P in plant biomass.

Results

At the end of experiment, earthworms wereabsent in the 0-10 cm layerlikely because of too harsh climatic conditions and lack of food.However, significant effects of earthworms were found on soil porosity: thesignificant decrease of bulk density in the plots with earthworms (Table 1) confirms the presence and activity of earthworms during a part of the experiment.

Soil properties

The soil analyzed at the beginning of theexperiment showed that available phosphorus content in plots of riceand maize+dolichuswas lower with than without earthworm addition (4.71 ± 0.93 vs 10.40 ± 1.16 mgP.kg^{-1})(Table 1). Conversely, at the end of experiment,the soil inoculated and not inoculated with earthwormsunder rice were almost similar with regard totheir available P content(6.66 ± 4.27 vs 7.05 ± 4.37mgP.kg^{-1})(Table 1).At harvest, the presence of earthwormsincreased P availability by 39 % to those of the initial soilwhile without earthworms, itdecreased by 29%.

Table 1: Comparison of bulk density and available P content in the different treatmentsat the beginning and at the end of experiment. Significant results(P <0.05) are in bold.

TREATMENT	**Bulkdensity (g cm^{-3})**		**Available P content (mg kg^{-1})**	
	initial	**final**	**initial**	**final**
With earthworms	1,16 ± 0,02a	1,13 ± 0,03 a	4,71 ± 0,93 b	6,66 ± 4,27 a
Without earthworms	1,13 ± 0,02a	1,18 ± 0,03 b	10,40 ± 1,16a	7,05 ± 4,37 a
P-value	0,391	**0,006**	**0,002**	0,858

Plant biomass and grain yields

Our study showed that legumes (dolichus) are less responsive to the presence of earthworms (Fig. 1). Aboveground biomass (dry weight)of rice in treatmentswith earthworms had higher values(3.495 ± 447 Kg.ha^{-1}) than those without earthworms (2.900 ± 241 Kg.ha^{-1}). Nevertheless, there was no significant effects forboth rice and maize aboveground biomass. The similar results were obtained for rice and maize grain yields (Fig. 2).

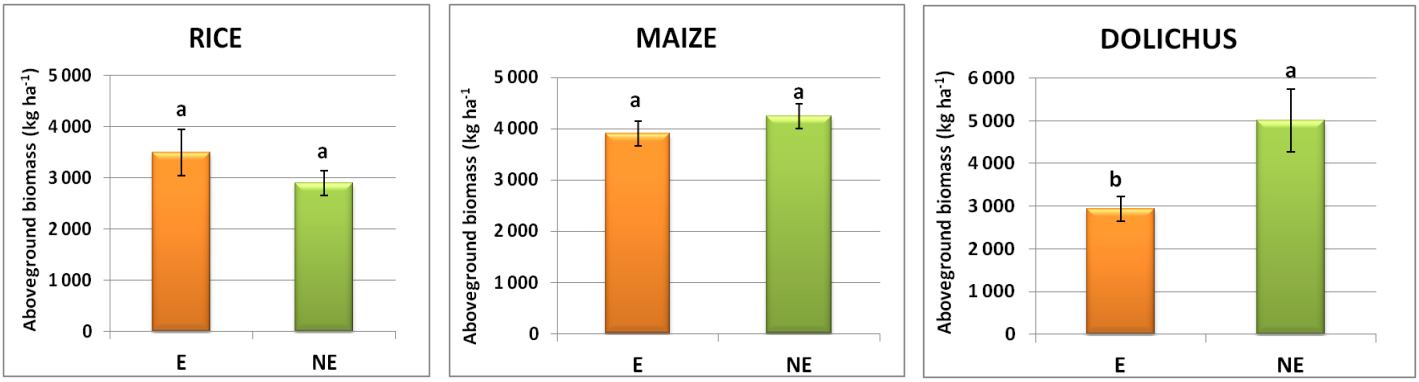

Figure 1 : aboveground biomass production in the different treatments (different letters indicatesignificant differences at p=5%). E: with earthworms; NE: without earthworms.

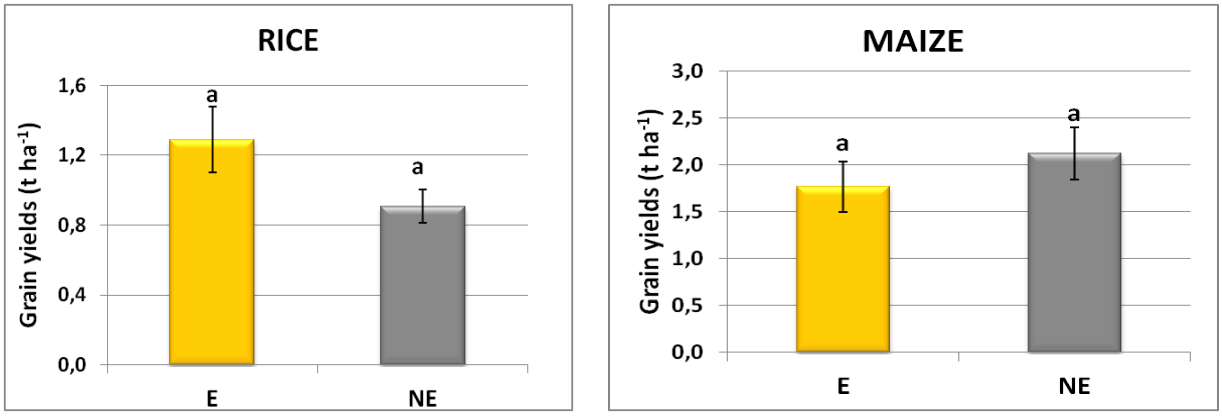

Figure 2 : Grain yields of rice and maize in the different treatments.Legend: Figure 1.

Nutrient acquisition

In the presence of earthworms, rice accumulated more nitrogen (3.417 ± 397 mgN.kg^{-1} for straw, 4.125 ± 624 mgN.kg^{-1}for grains) and phosphorus (186,78 ± 50,12 mgP.kg^{-1}for straw, 430,89 ± 86,60 mgP.kg^{-}1 for grains)thanin the absence of earthworms (for straw3.713 ± 236 mgN.kg^{-1}and 190,23 ± 23,41 mgP.kg^{-1}, for grains 2.924 ± 271 mgN.kg^{-1} and 339,54 ± 77,27 mgP.kg^{-1}).However, the differences between nitrogen and phosphorus acquisition at the whole plant level in presence or absence of earthworms tended to be less clear.

Discussions

Effect of earthworms on plant growth

Plant species of different functional groups respond differently to earthworms. They are not limited by the same resources and do not have the same resource allocation strategies (Brown *et al* 2004; Laossi*et al* 2009).Nevertheless, no significant difference is shown for grain yields of rice and maize in the presence or absence of earthworms.This is likely due to the disappearance of earthworms during the experiment: theclimatic and diet conditionsmaintained in the field duringthe experiment were probably not appropriate for thesurvival of the earthworms.

Effect of earthworms on P availability

Casts of P. corethrurusare enriched in available P;greater phosphate availability in casts canbe attributed to a greater pH of the gut content along the earthworm intestinal tractand to a stimulation of phosphatase-producing bacteria if compared to the soil (Le Bayonand Binet, 2006, Chapuis-Lardy *et al*, 2009, Bernard et al., 2014).

Conclusion

Our study showed that earthworms represent an important potential for intensifying crop production. Thepresence of earthworms enhances available P and increasessoil porosity.This experiment will be followed during three years to better understand the effect of earthworms. Earthworms will be introduced each year to ensure high densities.

References

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